

The K2-TESS Stellar Properties Catalog

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ABSTRACT

We provide a catalog of stellar properties for stars observed by the *Kepler* follow-on mission, K2. We base the catalog on a cross-match between the K2 Campaign target lists and the current working version of the NASA *TESS* target catalog. The resulting K2-TESS Stellar Properties Catalog includes value-added information from the TESS target catalog, including stellar colors, proper motions, effective temperatures, estimated luminosity class (dwarf/subgiant versus giant) based on reduced-proper-motion, and many other properties via cross-matches to other all-sky catalogs. Also included is the Guest Observer program identification number(s) associated with each K2 target. The K2-TESS Stellar Properties Catalog is available to the community as a freely accessible data portal on the Filtergraph system at: http://filtergraph.vanderbilt.edu/tess_k2campaigns.

1. Introduction: K2 and the Need for a Stellar Properties Catalog

The *Kepler* telescope was launched in March 2009 and delivered photometry for $\approx 200,000$ stars, all located in the same field between Cygnus and Lyra (Borucki et al. 2010; Burke et al. 2014). The main *Kepler* mission operated for about 4 years until after a second reaction wheel failed, such that the telescope could no longer be pointed at the original field with sufficient pointing stability. A new mission concept, *K2*, was then initiated (Howell et al. 2014), in which the telescope is pointed at the ecliptic plane with a new field observed along the ecliptic every three months. *K2* should permit discovery of small transiting exoplanets orbiting bright stars, as initial tests show that *K2* is capable of photometry with a precision of 20–50 parts per million for thousands of stars in each field (e.g., Vanderburg & Johnson 2014).

It is expected that the community will play a major role on the success of the *K2* mission. In particular, the target stars to be observed in each *K2* field—or Campaign—are selected from community proposals, and for the first eleven fields (Campaigns 0–10) the total number of targets has ranged from 7,000 to 40,000 stars. The brightest and the coolest dwarfs represent two of the most requested types of targets, together with very massive stars, known eclipsing binaries, and stars in open clusters. With the first *K2* data releases, the *Kepler* team has provided coordinates and Kepler magnitudes for all selected stars, but the provision of stellar properties is left as a community endeavor. With this document, we describe an online data portal that aims to provide estimated stellar properties of a large fraction of stars in each *K2* Campaign, based

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on a work-in-progress target catalog that is being developed by the NASA *TESS*¹ science team. Our hope is that this resource will serve the community for optimizing the science return of the *K2* mission, such as organizing followup observations of *K2* targets of interest, for a variety of scientific investigations.

2. The TESS Target Catalog

The Transiting Exoplanet Survey Satellite (TESS; Ricker et al. 2014) has been selected by NASA for launch in 2017 as an Astrophysics Explorer mission to search for planets transiting bright and nearby stars. During its two-year mission, TESS will monitor at ~ 1 -minute cadence at least 200 000 main-sequence dwarf stars with $I_C \approx 4$ –13 to search for planetary transits.

To optimize the TESS target stars for planet detection, the TESS Science Office’s target selection working group (TSWG) is developing a catalog of bright dwarf stars across the sky, from which a final target list for TESS can be drawn based on in-flight observation constraints yet to be determined. The basic consideration is to assemble a list of dwarf stars all over the sky in the effective temperature (T_{eff}) range of interest to TESS, bright enough for TESS to observe, and taking extra steps to include the scientifically valuable M-dwarfs. The overall approach is to first combine several all-sky star catalogs to serve as the basis for the target catalog, and then augment that with smaller valuable catalogs. We then apply cuts to select stars of the desired ranges in apparent magnitude and spectral type, and to eliminate evolved stars.

We use the 2MASS point source catalog as the starting point, since it is the one catalog that exists across the full range of magnitudes for TESS targets for the entire sky. We cross-match the 36,597,875 2MASS stars having $J < 13$ against the NOMAD, Tycho2, Hipparcos, APASS, and UCAC4 catalogs. The cross-match is done based primarily on position (1 arcsec tolerance). We also include smaller catalogs of nearby high-proper-motion M-dwarfs. That combined dataset is the Augmented TESS Target Catalog (ATTC), which at the time of this writing contains 35.8 million stars.

We have developed a procedure to estimate T_{eff} based on empirical relationships of stellar $V - K$ color. The procedure is as follows.

The color–temperature relation for dwarfs as a function of $V - K_S$ is in two pieces:

1. For $V - K_S$ in the range $[-0.10, 5.05]$ and $[\text{Fe}/\text{H}]$ in the range $[-0.9, +0.4]$, we use the AFGKM relation from Huang et al. (2015):

$$\begin{aligned} X &= V - K_S \text{ (de - reddened)} \\ Y &= [\text{Fe}/\text{H}] \\ \theta &= 0.54042 + 0.23676X - 0.00796X^2 - 0.03798XY + 0.05413Y - 0.00448Y^2 \\ T_{\text{eff}} &= 5040/\theta \end{aligned}$$

The scatter of this calibration is 2% in T_{eff} , which should be added in quadrature to whatever errors come from photometric uncertainties propagated through the above equation.

2. For redder $V - K_S$ values in the range $[5.05, 8.468]$, use the relation from Casagrande et al. (2008),

¹Transiting Exoplanet Survey Satellite (TESS) information is available at: <http://tess.gsfc.nasa.gov>.

shifted by +205.26 K to meet with the one above at $V - K_S = 5.05$:

$$\begin{aligned} X &= V - K_S \text{ (de - reddened)} \\ \theta &= -0.4809 + 0.8009X - 0.1039X^2 + 0.0056X^3 \\ T_{\text{eff}} &= 5040/\theta + 205.26 \end{aligned}$$

The scatter of this calibration is only 19 K, according to the paper, which should be added in quadrature to whatever errors come from photometric uncertainties propagated through the above equation. Note that this Casagrande relation does not include metallicity terms, but those authors claim that the dependence on metallicity is weak for M stars with $T_{\text{eff}} > 2800$ K.

The above expressions provide a continuous color-temperature relation from 2444 K to 9755 K. For stars with $V - K_S$ outside of the ranges of validity, we report $T_{\text{eff}} = \text{NULL}$.

Finally, for completeness, we provide a similar color-temperature relation for red giants, also taken from Huang et al. (2015):

$$\begin{aligned} X &= V - K_S \text{ (de - reddened)} \\ Y &= [\text{Fe}/\text{H}] \\ \theta &= 0.46447 + 0.30156X - 0.01918X^2 - 0.02526XY + 0.06132Y - 0.04036Y^2 \\ T_{\text{eff}} &= 5040/\theta \end{aligned}$$

which is valid for $V - K_S$ in the range [1.99, 6.09] and $[\text{Fe}/\text{H}]$ in the range $[-0.6, +0.3]$. The scatter in T_{eff} is 1.7%.

Note that the above relations are all based on $V - K_S$ color. We have a K_S magnitude for nearly every object since 2MASS is the base catalog for the entire TIC. If a V mag is available from APASS, we adopt it (for stars with $V > 10$), otherwise we adopt V_T from Tycho, or the V magnitude from Hipparcos. Finally, if none of the above are available, adopt the UCAC V unless the V from UCAC is flagged as unreliable. In all cases, we convert the adopted V to Johnson V using standard conversion relations.

Since spectroscopically determined surface gravities are not available for most stars in the ATTC, we use the reduced proper motion (RPM) statistic, which Collier Cameron et al. (2007) found to be useful for separating giant stars from dwarfs. Note that the RPM method does not robustly disambiguate subgiants ($3.5 < \log g < 4.1$) from dwarfs ($\log g > 4.2$), so they will be included in the dwarf group. However, the method cuts at about $\log(g) = 3.5$. For all targets in the ATTC that have recorded proper motions, μ , we compute $\text{RPM}_J = J + 5 \log \mu$ (note that this differs by an offset of 5 from the usual definition of $\text{RPM}_J = J + 5 \log \mu + 5$). According to this method, stars with RPM_J less than an empirically-determined cut in RPM_J vs. $J - H$ parameter space are taken to be non-giants, i.e. either dwarfs or subgiants. We conservatively flag stars that are within 2σ of the RPM_J threshold as possible giants. Figure 1 illustrates the separation of K2 stars into giants and dwarfs/subgiants according to the RPM_J cut.

3. The K2-TESS Stellar Properties Catalog

We have cross-matched the ATTC (see Sec. 2) against the stars observed in all K2 Campaigns² (as of this writing this includes Campaigns 0–10). Since the K2 target stars have mostly been drawn from the

²K2 Campaign target lists obtained from: <http://keplerscience.arc.nasa.gov/K2/Fields.shtml>.

EPIC catalog³, and since the Campaign 0 Engineering Run target list² included target coordinates that were not specified with the precision of the EPIC coordinates, we matched the ATTC directly to EPIC through RA and Dec coordinates (1 arcsec tolerance). We then select from that overall cross-match the observed K2 campaign stars by their EPIC IDs. We do not include in the released K2-TESS catalog $\sim 29,000$ stars from K2 Campaigns 0–10 that do not have EPIC coordinates (these are mostly custom apertures for open clusters and solar system objects). The current cross-matched catalog for Campaigns 0–10 includes 117,521 stars with $J < 13$.

In addition, while not part of the planned TESS Target Catalog, we have also matched the K2 target stars against all fainter 2MASS and UCAC4 stars in order to provide an additional cross-matched “faint extended” K2-TESS catalog for $J > 13$. We caution that this faint extended catalog is provided as-is. In particular, the performance of the RPM giant/dwarf separation, and of the color- T_{eff} relations, have not been as carefully vetted for these fainter stars.

Based on the distribution of stars in the $(V - K) - (J - H)$ plane reported in Bessel & Brett (1988), we developed a method to assign dereddened T_{eff} to most of our target stars and report these values in the database.

We also cross-matched the catalog with stellar characteristics from APOGEE-1 (Alam et al. 2015), RAVE DR4 (Kordopatis et al. 2013), and LAMOST DR1 (Luo et al. 2015). For the 192,884 stars from K2 campaigns 0 to 10 we find 1592 stars with stellar characteristics from Apogee-1, 5336 stars in Rave, 6262 A-K stars from LAMOST, and 1167 M-dwarfs in LAMOST-M (these do not have T_{eff} reported in the LAMOST catalog).

The K2-TESS Stellar Properties Catalog for $J < 13$ and the faint extended K2-TESS catalog for $J > 13$ are available through the Filtergraph data portal system (Burger et al. 2013) at a dedicated URL: http://filtergraph.vanderbilt.edu/tess_k2campaigns. Figure 2 gives an example map display utilizing the portal, and Table 1 gives a listing of the data fields included in the catalog.

The K2-TESS Stellar Properties catalog is being provided as a service to the community. We intend to regularly update the catalog on the Filtergraph data portal as additional K2 Campaign targets are observed. The data portal website includes fair-use terms and contact information. We expect to have a significantly improved portal in the next two months based on the new TESS Input Catalog matches to Tycho-2, the inclusion of bright star V magnitudes, and improved calculations of T_{eff} and dereddened T_{eff} .

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³The K2 Ecliptic Plane Input Catalog (EPIC) available at: <https://archive.stsci.edu/k2>.

| Field name | Description |
|-----------------------|---|
| tmname | Object identifier from the 2MASS catalog |
| ra, dec | Right ascension and declination from 2MASS catalog |
| glong, glat | Galactic longitude and latitude from RA and Dec. |
| ucacname | UCAC4 catalog identifier |
| tycname | Tycho catalog identifier |
| hipno | Hipparcos catalog identifier |
| k2name | <i>K2</i> /EPIC target catalog identifier |
| k2camp | <i>K2</i> Campaign number during which target was observed |
| J, H, K | Apparent <i>JHK</i> magnitudes from 2MASS |
| V | Apparent <i>V</i> magnitude from Vsrc |
| Vsrc | Catalog source of <i>V</i> magnitude |
| Verr | Reported error on <i>V</i> magnitude from Vsrc |
| pmra, pmdec | Proper motions in RA and Dec from UCAC4 catalog |
| isdwarf | Flag indicating 1 for likely dwarf/subgiant, 0 for likely giant, based on RPM_J criterion |
| teff | Estimated T_{eff} based on color- T_{eff} relation using photometry from teffsrc |
| teffsrc | Catalog source of photometry used to derive T_{eff} (teff) |
| tefferr | Propagated uncertainty on T_{eff} (teff) |
| drteff _i | Up to 4 solutions for de-reddened T_{eff} |
| kepmag | Apparent magnitude in the <i>Kepler</i> bandpass, taken from EPIC catalog |
| investids | <i>K2</i> GO ID numbers associated with target (multiple IDs separated by ' ') |
| apgteff, apgtefferr | T_{eff} and error from APOGEE 1 |
| apglogg, apgloggerr | $\log(g)$ and error from APOGEE 1 |
| apgmh, apgmherr | metallicity and error from APOGEE 1 |
| raveteff, ravetefferr | T_{eff} and error from RAVE DR4 (stellar characteristics) |
| ravelogg, raveloggerr | $\log(g)$ and error from RAVE DR4 (stellar characteristics) |
| ravemet, ravemeterr | metallicity and error from RAVE DR4 (stellar characteristics) |
| raveteffv | T_{eff} from RAVE DR7 (radial velocity pipeline) |
| raveloggv | $\log(g)$ and error from RAVE DR4 (radial velocity pipeline) |
| lmakteff, lmaktefferr | T_{eff} and error from LAMOST DR1 |
| lmaklogg, lmakloggerr | $\log(g)$ and error from LAMOST DR1 |
| lmakfeh, lmakfeherr | metallicity and error from LAMOST DR1 |
| lmmsubclass | subclass for M-stars from LAMOST DR1 |

Table 1: *Description of fields in the K2-TESS Stellar Properties catalog and K2-TESS faint extended catalog.*

Casagrande, L., Flynn, C., & Bessell, M. 2008, MNRAS, 389, 585

Collier Cameron, A., Wilson, D. M., West, R. G., et al. 2007, MNRAS, 380, 1230

Howell, S. B., Sobek, C., Haas, M., et al. 2014, PASP, 126, 398

Huang, Y., Liu, X.-W., Yuan, H.-B., et al. 2015, MNRAS, 454, 2863

Kordopatis, G., Gilmore, G., et al., 2013, The Astronomical Journal, 146:134

Luo, A.-L., Zhao, Y.-H., et al. (2015), arXiv:1505.01570

Ricker, G. R., Winn, J. N., Vanderspek, R., et al. 2014, Proc. SPIE, 9143

Schlegel, D. J., Finkbeiner, D. P., Davis, M., ApJ500 : 525–553, 1998 June 20

Vanderburg, A., & Johnson, J. A. 2014, arXiv:1408.3853

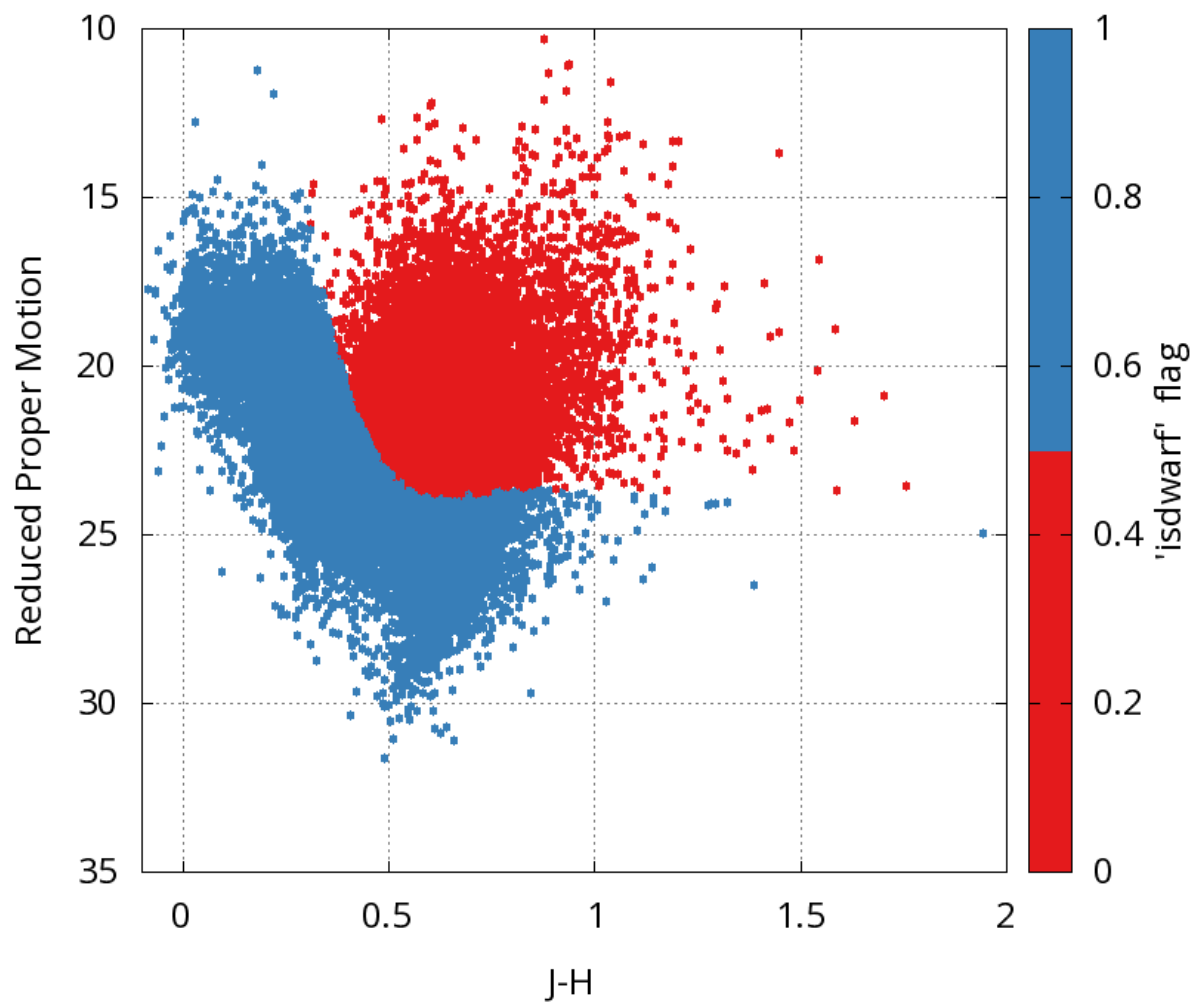


Fig. 1.— We adopt the reduced-proper-motion diagram of Collier Cameron et al. (2007) to separate stars into likely giants (red) versus likely dwarfs (blue). Note that subgiants are generally mixed in with the putative dwarfs.

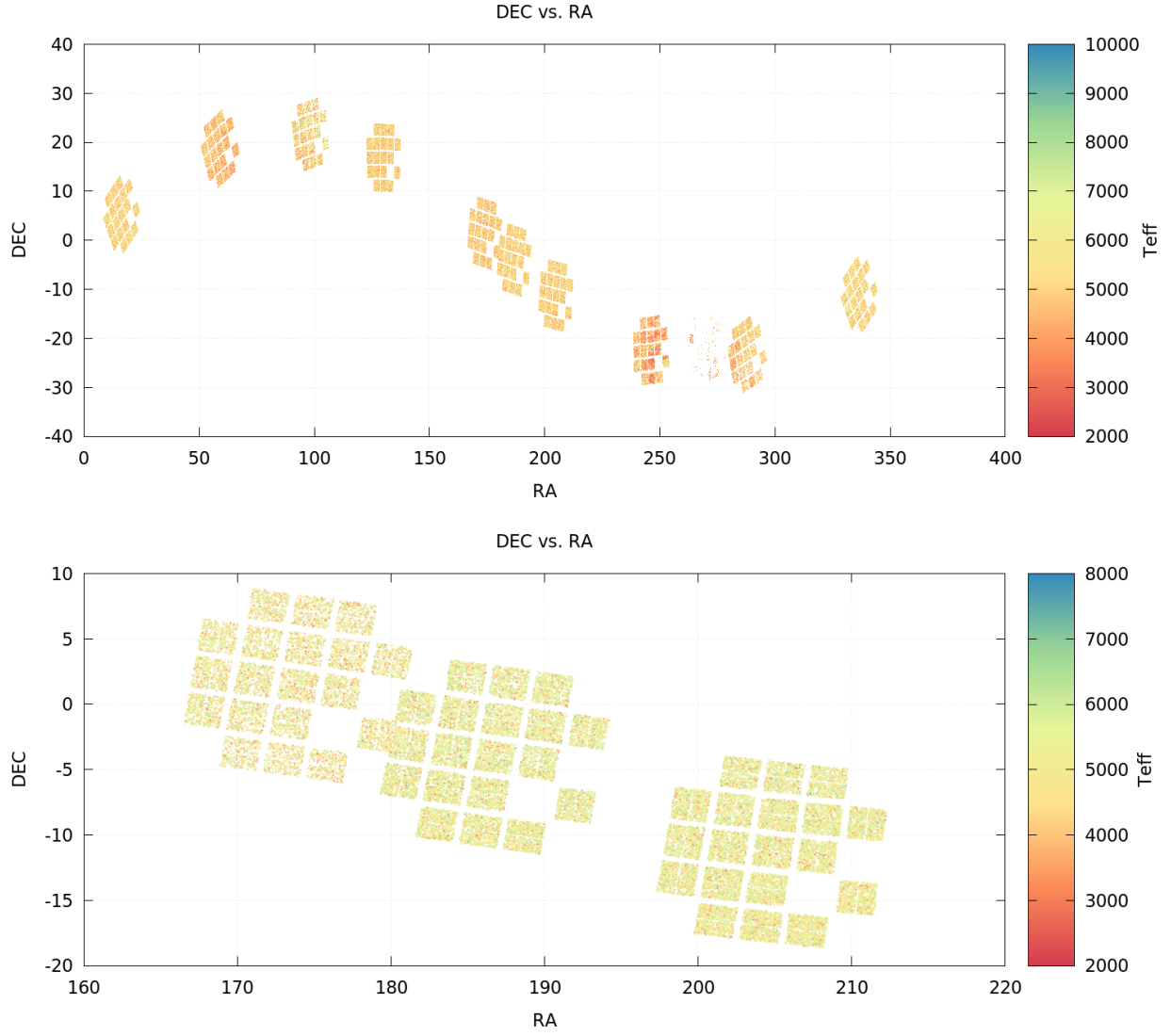


Fig. 2.— Example map displays of all stars with $J < 13$ from the K2-TESS catalog on the Filtergraph data portal system. (Top) Full map showing Campaigns 0–10. (Bottom) Zoom of campaigns 1, 10 and 6.